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Indian Standard

METHOD OF TEST FOR ELECTRIC STRENGTH OF SOLID INSULATING MATERIALS AT POWER FREQUENCIES

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *February* 1964

Indian Standard

METHOD OF TEST FOR ELECTRIC STRENGTH OF SOLID INSULATING MATERIALS AT POWER FREQUENCIES

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Indian Standard

METHOD OF TEST FOR ELECTRIC STRENGTH OF SOLID INSULATING MATERIALS AT POWER FREQUENCIES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 14 August 1963, after the draft finalized by the Insulating Materials Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 With the advent of indigenous manufacture of electrical insulating materials, need has been felt to have Indian Standards prescribing the test conditions and procedures for determining the performance characteristics of insulating materials with a view to ensuring uniformity in results of tests carried out by different agencies. A series of standards on methods of testing electrical insulating materials is being issued and this standard, which is one in the series, prescribes the method of determination of electric strength of solid insulating materials and filling compounds for industrial purposes at power frequencies.

0.2.1 Other standards so far published in this series are:

IS : 2259-1963 METHODS OF TEST FOR DETERMINATION OF INSULATION RESISTANCE OF SOLID INSULATING MATERIALS

IS : 2260-1963 RECOMMENDATIONS FOR THE CONDITIONING AND TESTING OF ELECTRICAL INSULATING MATERIALS

0.2.2 Determination of the electric strength of the insulating oils is covered in IS : 335-1963 Specification for Insulating Oil for Transformers and Switchgear (*Revised*).

0.2.3 Separate specifications for different insulating materials are also being prepared. The following specifications have been issued so far:

IS : 2448 (PART I)-1963 SPECIFICATION FOR ADHESIVE INSULATING TAPES FOR ELECTRICAL PURPOSES PART I TAPES WITH COTTON TEXTILE SUBSTRATES

IS : 2464-1963 SPECIFICATION FOR BUILT-UP MICA FOR ELECTRICAL PURPOSES

0.3 Specifying the electric strength of an insulating material has no significance without providing complete details of test conditions, since the electric strength is affected by many factors. These include:

a) the frequency, wave-form and time of voltage application;

b) the thickness and homogeneity of the specimen and the presence of mechanical strain;

c) the ambient temperature, pressure and humidity;

d) the presence of gaseous inclusions, moisture or other contamination;

e) the shape, size and thermal characteristics of test electrodes; and

f) the electrical and thermal characteristics of the ambient medium.

0.3.1 The effect of all these factors should be considered while investigating new materials, but for comparative tests it is only necessary to define particular conditions enabling rapid discrimination between materials and which can be used for quality control and similar tests. The test prescribed in this standard is designed for this purpose only.

0.4 More than one method is available for determining the electric strength of an insulating material, but the results given by different methods are not directly comparable and it should be noted that the electric strength of materials decreases as the thickness of the specimen between the electrodes increases and with increasing time of voltage application.

0.5 Insulating materials with a high dielectric strength, as measured in accordance with this standard, may not necessarily resist long term degradation processes, such as erosion or chemical deterioration by discharges or electrochemical deterioration in the presence of moisture, which may cause eventual failure in service at much lower stresses. On the other hand, if discharges in insulation are eliminated by appropriate design and construction, the values obtained by the test method prescribed in this standard may be exceeded.

0.6 In preparing this standard, assistance has been derived from the following:

IEC Doc : 15 (Secretariat) 50 Recommended Methods of Test for Electric Strength of Insulating Materials at Power Frequencies. International Electrotechnical Commission.

B.S. 2918 : 1957 Electric Strength of Solid Insulating Materials at Power Frequencies. British Standards Institution.

0.7 Wherever a reference to any Indian Standard appears in this standard, it shall be taken as a reference to the latest version of the standard.

0.8 Metric system has been adopted in India and all quantities and dimensions appearing in this standard are given in this system.

0.9 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960 Rules for Rounding Off Numerical Values (*Revised*).

1. SCOPE

1.1 This standard lays down test conditions and procedure for the determination of electric strength of solid insulating materials and filling compounds for industrial purposes at power frequencies.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Crest Factor (of a Voltage) — The ratio of the peak value of the voltage to its root mean square value.

2.2 Electric Strength (of an Insulating Material) — The voltage at which breakdown occurs, under the prescribed conditions of test, divided by the distance between the electrodes to which the voltage is applied.

3. GENERAL

3.1 Surrounding Medium — Insulating materials should preferably be tested in the medium in which they are to be used. If this presents difficulties on account of flash-over or excessive discharges, the tests should be carried out in a medium of higher electric strength, for example, an insulating liquid.

3.1.1 Materials, which are to be used in air and for which impregnation by an insulating liquid is essential for their properties, or materials having properties which will be improved by immersion, should not be tested in insulating liquid. For example, unimpregnated press board should not be tested in oil.

3.1.2 When tests are conducted in an insulating liquid, the liquid should meet the requirements of relevant standard [*see also* IS : 335-1963 Insulating Oil for Transformers and Switchgear (*Revised*)]. It is necessary to ensure adequate electric strength and resistivity of the liquid as reduction may result in an increase in measured electric strength of the specimen.

NOTE — Breakdown values obtained in liquid may not be comparable with those obtained in air.

3.2 Conditioning of Test Specimen — The electric strength of most of the insulating materials varies with the temperature and moisture content. For information concerning the conditioning of a particular material, reference should be made either to the specification covering that material or to IS : 2260-1963 Recommendations for the Conditioning and Testing of Electrical Insulating Materials.

3.3 Conditions of Test

3.3.1 *Tests in Air* — Tests in air at elevated temperature may be made in any well-designed oven of size sufficient to accommodate the test piece and the electrodes, without flash-over occurring at the maximum test voltage. The oven should be provided with some means of circulating the air, so that nearly uniform and constant temperature is maintained around the test piece. It should also be provided with a thermometer, thermocouple or other means for measuring the temperature as near the point of test as practicable.

3.3.2 *Tests in Liquids* — Tests in liquid may be made in a liquid bath provided with suitable means for circulating the liquid, so that the temperature is substantially uniform around the test specimen. It should also be provided with a thermometer or thermocouple for measuring the temperature as near the point of test as practicable.

4. ELECTRICAL EQUIPMENT

4.1 The details of equipment required for determining the electrical strength of insulating materials in accordance with this standard are given in Appendix A.

5. TEST SPECIMENS AND ELECTRODES

5.0 General

5.0.1 *Test Specimen* — In the preparation of test specimens from solid materials care should be taken that the surfaces in contact with the electrodes are parallel, and as flat and smooth as the material allows. The area of test specimens should be sufficient to prevent flash-over under the conditions of test.

5.0.1.1 For recessed test pieces, the thickness shall be measured on material undisturbed by breakdown but as near the point of breakdown as possible.

5.0.1.2 For unrecessed test pieces of approximately uniform thickness, the thickness shall be the average thickness of the test piece measured, as specified for the material involved.

5.0.2 *Electrodes* — The electrodes should be kept clean and free from pitting caused by arcing. When the electrodes are not of the same size, the larger of the two should be connected to the earthed end of the high voltage winding of the testing transformer, or to the end nearest the earth potential if both poles of the transformer are insulated. The leads to high and low voltage electrodes should not appreciably affect the electric field configuration. The lead to the high voltage electrodes should not tilt or otherwise move the electrode or affect the pressure on the specimen.

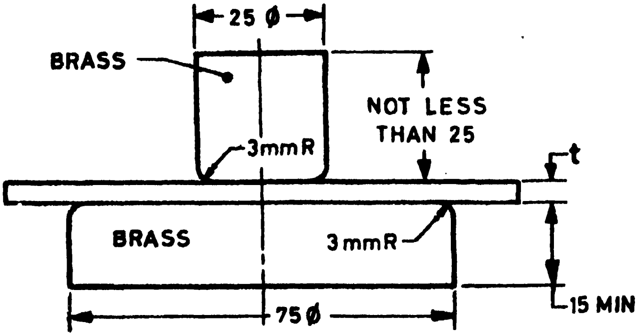
5.1 For Tests on Non-laminated Materials and Normal to Laminae of Laminated Materials

5.1.1 *Boards and Sheets (Up to and Including 3 mm Thick), and Papers, Fabrics and Films* — The electrodes shall consist of two brass cylinders with the sharp edges removed to give a radius of 3 mm . One electrode (upper electrode) shall be approximately 25 mm in diameter and not less than 25 mm in height. The other electrode (lower electrode) shall be 75 mm in diameter and at least 25 mm in height. These electrodes shall be arranged coaxially as in Fig. 1A.

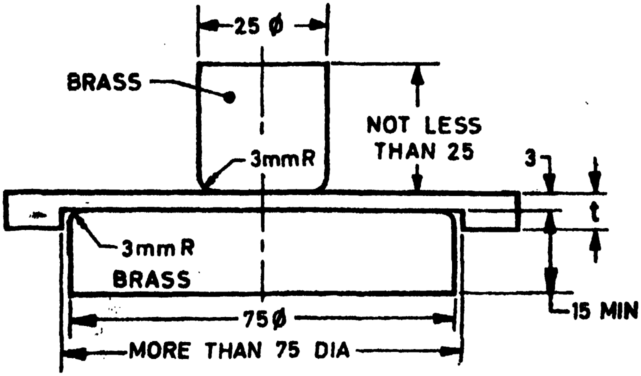
5.1.2 *Boards and Sheets More Than 3 mm Thick* — The electrodes specified in **5.1.1** shall be used on the full thickness of the material; alternatively, the 75 mm diameter electrode may be placed in a recess machined to reduce the thickness of the material to 3 mm as in Fig. 1B.

5.1.3 *Narrow Strips or Tapes* — The electrodes shall consist of two brass rods, each 6 mm in diameter, mounted vertically one above the other in a jig so that the specimen is held between the faces of the squared ends of the rods. The upper and lower electrodes shall be coaxial. The sharp edges of the squared ends shall be removed to give a radius of approximately one millimetre. The upper electrode shall weigh 50 ± 2 g. In Fig. 2 is shown a convenient arrangement to which may be added suitable means for stretching tapes; these may consist of a rigid frame carrying two similar clamps on opposite sides. One of the clamps, which may be a rod, may be so arranged that it can be rotated by a handle. To prevent flash-over around the edges of narrow tapes, the test specimen shall be clamped using strips of varnished cloth overlapping the edges of the tape. Alternatively, gaskets fitting round the electrodes may be used provided that there is an annular space between electrode and gasket of about 1·5 mm.

5.1.4 *Flexible Tubing and Sleeving* — For tubing up to 25 mm internal diameter, straight metal wires or rods shall be used for the inner



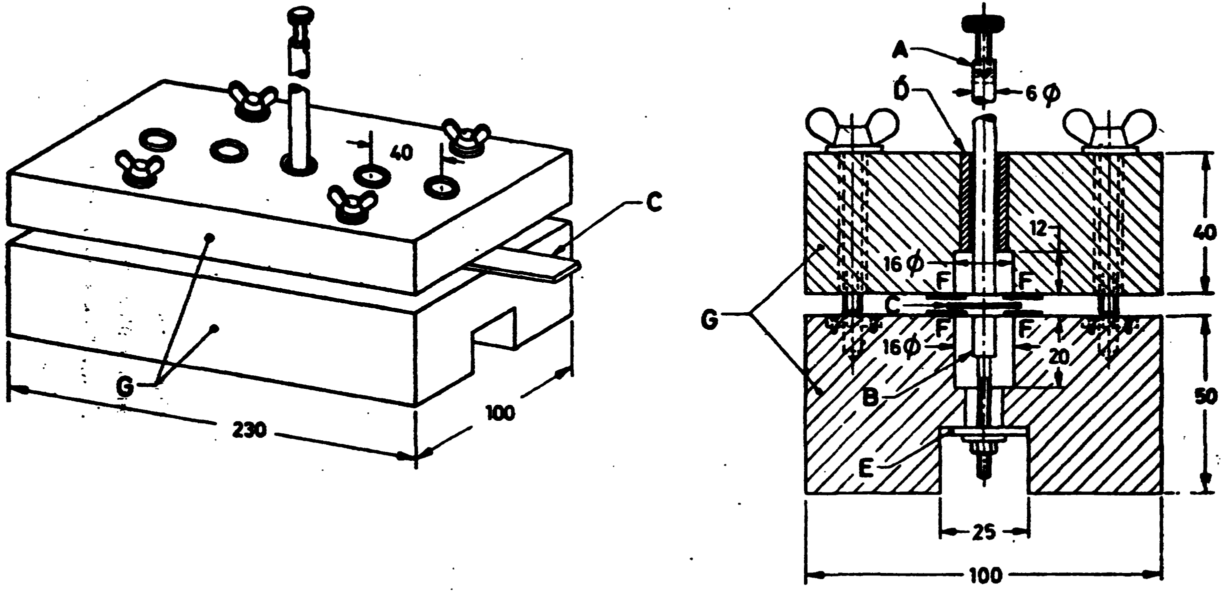
1A Upto and including 3 mm thick



1B More than 3 mm thick

All dimensions in millimetres.

Fig. 1 Electrode Arrangement for Tests on Boards and Sheets



2A General Arrangement of Apparatus

2B Section of Apparatus Through Electrodes with Top Slightly Raised

A = Upper electrode which can easily fit in bush D;
B = Lower electrode;
C = Sample under test;
D = Brass bush with inside diameter just sufficient to clear 6-mm rod;
E = Brass strip 25-mm wide connecting all lower electrodes;
F = Pieces of varnished cloth strip overlapping edges of sample; and
G = Blocks of suitable insulating material, for example, a paper filled laminate.

All dimensions in millimetres.

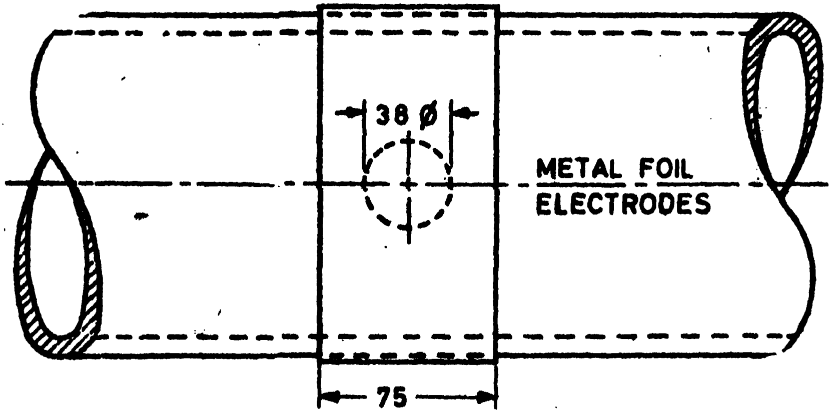
Fig. 2 Typical Example of Electrode Apparatus for Electric Strength Test on Tape

electrode. The nearest *standard size of wire or rod that fits snugly without stretching the tubing shall be used as it is slipped on to the wire. For the outer electrode, a strip of metal foil 25 mm in width and not more than 0·025 mm in thickness shall be applied snugly around the tubing. For tubing greater than 25 mm internal diameter, the specimen shall be cut longitudinally on one side and tested as described in 5.1.3. Alternatively, electrodes may be provided by the use of metal powder or water, the latter being restricted to sleeving unaffected by immersion in water.

5.1.5 *Rigid Tubes (Having an Internal Diameter Up to and Including 100 mm)* — The outer electrode shall be a band of metal foil 25 mm in width. The inner electrode may be either a closely fitting internal conductor, for example, rod, tube, metal foil, or powder, and it should make good contact with the inner surface. In each case, the ends of the inner electrode should extend for at least 25 mm beyond the ends of the outer electrode.

NOTE — Where no adverse effect is likely, petroleum jelly may be used for attaching foil to the inner surface.

5.1.6 *Hollow Cylinders (Having an Internal Diameter Greater Than 100 mm)* — The outer electrode shall be a band of metal foil 75 mm in width and the inner electrode a disc of metal foil 38 mm in diameter, flexible enough to conform to the curvature of the cylinder. The arrangement shall be as shown in Fig. 3.



All dimensions in millimetres.

FIG. 3 ELECTRODE ARRANGEMENT FOR TESTS ON CYLINDERS

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*See IS : 1137-1959 Thicknesses of Sheet and Diameters of Wire and IS : 1136-1958 Sizes of Metal Strip, Sheet, Bars (Round and Square), Flats and Plate (for Structural and General Engineering Purposes).

5.1.7 *Moulded and Cast Materials* — The electrodes specified in **5.1.1** shall be used with the test specimen in sheet form preferably 3 mm thick (prepared under conditions specified in the standard covering that material).

5.1.8 *Varnishes* — The electrode arrangement described in **5.1.1** or **5.1.3** shall be used for testing varnishes. Test specimens shall consist of varnish films on suitable supporting materials, such as paper, thin glass fabric, or thin copper sheet. If the varnish is on the copper sheet, this shall replace the larger electrode (lower electrode) described in **5.1.1**.

NOTE — As the results are very materially affected by the nature and thickness of the supporting material, and the thickness of the varnish film, these should be prescribed in the specification for varnish.

5.1.9 *Filling Compounds* — Two 12·5 mm diameter metal spheres, arranged horizontally 1·25 mm apart, and embedded in the compound, shall be used as electrodes.

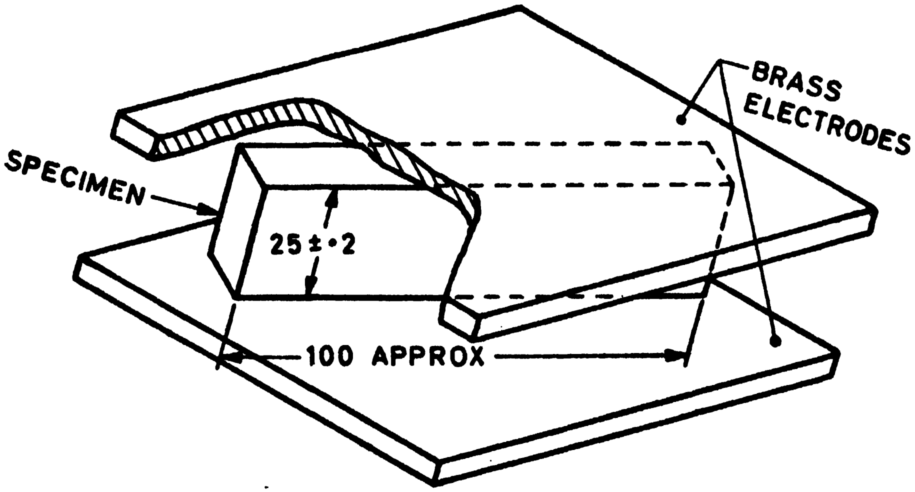
NOTE — Care shall be taken to avoid cavities between the electrodes.

5.2 For Tests Parallel to the Surface and Along the Laminae — These are suitable primarily for proof tests to establish whether a material will withstand a specified voltage. In some cases, for example, specimens conditioned in water, it may be possible to secure breakdown of the specimens themselves. Usually, however, surface flash-over occurs first in the ambient medium near the test specimen surface. When tests are conducted at elevated temperatures, prior breakdowns in the ambient medium are less likely. They may not always be prevented and they should be reported if they occur.

5.2.1 *Boards and Sheets* — The electrodes shall consist of two parallel metal plates and the test specimen shall be placed between them (*see* Fig. 4). The electrodes shall be of size sufficient to overlap the edges of the test pieces by not less than 15 mm and care shall be taken to ensure good contact over the whole area of these edges. The edges and corners of the electrodes should be suitably radiused when necessary to avoid flash-over from edge to edge.

5.2.1.1 The test specimen shall be rectangular, approximately 100 mm in length and of the thickness of the material under test. The width of the test specimen shall be 25·0 ± 0·2 mm and the long edges shall be cut as parallel planes at right angles to the surface of the material. For thin materials, two test specimens may be suitably placed (that is, with their long edges at a convenient angle) to support the upper electrode.

NOTE — These electrodes are not suitable for tests on sheet materials of thickness less than 1·5 mm.



All dimensions in millimetres.

Fig. 4 Electrode Arrangement for Testing Boards and Sheets Parallel to the Surface and Along the Laminae

5.2.2 *Tubes and Cylinders* — The parallel plated electrode arrangement described in **5.2.1** shall be employed. The electrode shall be of size sufficient to overlap the edges of the test specimen by not less than 15 mm and care shall be taken to ensure good contact over the whole area of the ends of the test specimens. Where supporting or balancing of the upper electrodes is necessary, two or three test specimens may be used.

5.2.2.1 The test specimen shall be a complete ring, or a 100 mm portion of a ring if the circumference of cylinder is greater than 100 mm. The axial length of specimen shall be 25·0 ± 0·2 mm. The curved edges of the test specimen shall be finished as parallel planes at right angles to the axis of the tube or cylinder.

6. TEST VOLTAGE

6.1 The test voltage applied to the dielectric, when the test specimen is in circuit, shall be approximately of sine-wave form with crest factor equal to $\sqrt{2} \pm 5$ percent, that is 1·35 to 1·49.

6.1.1 The crest factor may be checked by means of an oscillograph, a sphere gap or a crest voltmeter in conjunction with an RMS voltmeter. The measurement should be made across the material under test.

6.2 The test voltage shall be expressed as its peak value divided by $\sqrt{2}$.

6.3 The frequency of the test voltage shall be between 40 and 60 c/s.

6.4 Measurement

6.4.1 The peak voltage may be measured directly by means of a peak voltmeter. Alternatively, the voltage may be determined by a voltmeter suitably connected to the input or output side of the testing transformer or to a voltmeter winding provided thereon; if this alternative procedure is adopted, the instrument used should be calibrated against a sphere gap up to the full voltage which is to be measured.

6.4.2 The ratio of the voltage derived from the sphere gap to the voltage indicated on the auxiliary instrument may be dependent upon the presence of the test object, or of the sphere gap. Therefore, it is important that the test object, or an equivalent load, should be in the circuit during the calibration. The sphere gap may be disconnected during the actual test if its absence is known to have a negligible influence on the voltage ratio [*see also* IS : 1876-1961 Method for Voltage Measurement by Means of Sphere Gap (One Sphere Earthed)].

6.5 Rate of Rise — Rate of rise of voltage may be calculated from the time required to raise the voltage between two prescribed values. When motor-driven regulating equipment is used, the speed-control rheostat for any particular testing transformer may be calibrated in terms of voltage rise.

7. APPLICATION OF VOLTAGE

7.1 Rapidly Applied Voltage, or Short Time Test — The voltage shall be raised from zero at a uniform rate such that breakdown occurs on an average in between 10 or 20 seconds. This procedure requires some previous knowledge of the characteristics of the material; otherwise one or two preliminary tests are needed. If a number of tests is being made, it shall be considered satisfactory, if the average time to breakdown lies within 10 to 20 seconds, even if some of the individual durations are outside this range. This voltage shall be used for determining the starting voltage on the subsequent test for determination of the electric strength of the insulating material (*see* 7.2).

7.2 Twenty-Second Step Test — The nearest voltage to 40 percent of the probable breakdown voltage as determined by the rapidly applied voltage test (*see* 7.1) shall be selected from Table I and applied to the test specimen. If the test specimen withstands this voltage for 20 seconds without failure, the next higher and subsequent voltages given in Table I shall then be successively applied for 20 seconds until failure occurs. The increase in voltage shall be made as quickly as possible and the time spent in raising the voltage shall be included in the period of 20 seconds at the higher voltage.

NOTE — When it is required to apply a predetermined voltage for the purpose of a proof or withstand test, the voltage shall be raised to the required value as rapidly as possible, consistent with its accurate attainment without any transient over-voltage. This voltage shall then be maintained at the required value for the specified duration.

7.2.1 The electric strength shall be the highest voltage which is withstood for 20 seconds without breakdown.

TABLE I SUCCESSIVE VOLTAGES TO BE APPLIED (Kilovolts Peak/$\sqrt{2}$)

(*Clause* 7.2)

0·50	0·55	0·60	0·65	0·70	0·75	0·80	0·85	0·90	0·95					
1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9					
2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8
5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5					
10	11	12	13	14	15	16	17	18	19					
20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
50	55	60	65	70	75	80	85	90	95	100				
	110	120	130	140	150	160	170	180	190	200				

8. CRITERION OF BREAKDOWN

8.1 Dielectric breakdown is accompanied by an increase of current flowing in the circuit and by a decrease of voltage across the sample. The increased current may trip a circuit-breaker or blow a fuse. However, tripping of a circuit-breaker may be influenced sometimes by flashover, specimen charging, leakage or corona currents, equipment magnetizing current, or malfunctioning. It is, therefore, essential that the circuit-breaker is well co-ordinated with the characteristics of the test equipment and the material under test. Otherwise, the circuit-breaker may operate without breakdown of the specimen, or fail to operate when breakdown has occurred. This may not provide a positive criterion of breakdown. Even under the best conditions, prior breakdowns in the ambient medium may occur and observations should be made to detect them during tests. The results of such observations should be reported.

8.2 Where tests are made through a material, there is usually no doubt when breakdown has occurred, as subsequent visual inspection readily shows the actual breakdown channel which may be filled with carbon.

8.3 However, in tests parallel to the surface, it is advisable to confirm breakdown by re-applying twice, a voltage less than the first apparent breakdown, to check that subsequent failures occur at lower values. A convenient practice has been found to be the re-application of half the breakdown voltage, followed by increase to failure by the same procedure as in the first test.

9. NUMBER OF TESTS

9.1 Unless otherwise specified, five tests shall be made and the electric strength determined from the average of the test results. If any test result deviates more than 15 percent from the average, five additional tests should be made. The electric strength shall then be determined from the average of 10 results.

10. TEST REPORT

10.1 Unless otherwise specified, the report shall include the following:

a) Date of test;

b) Description of the material;

c) The number of test specimens;

d) The thickness or average thickness of the test specimen;

e) The surrounding medium during the test;

f) The preconditioning treatment before test, and the conditions of temperature and atmospheric humidity when testing in air and the temperature of the liquid when testing in a liquid;

g) The electrode system;

h) The breakdown voltage at each puncture;

j) The maximum, minimum and average breakdown voltage of each test specimen;

k) The average kV per centimetre or V per millimetre for each test specimen;

m) The duration of the test (for proof test only);

n) The method of application of the voltage;

p) In the 20-Second Step Test, the value of the initially applied voltage and the value of the voltage at each step;

q) An indication of the type of breakdown (or damage in proof tests); and

r) The means by which varnish is supported.

APPENDIX A

(*Clause* 4.1)

EQUIPMENT FOR DETERMINING ELECTRIC STRENGTH OF INSULATING MATERIAL

A-0. GENERAL

A-0.1 The equipment required for determining the electric strength of the insulating material in accordance with this standard usually comprise the following:

a) High Voltage Transformer,

b) Voltage Controlgear,

c) Protective Gear, and

d) Measuring Instruments (*see* 6.4).

A-1. HIGH VOLTAGE TRANSFORMER

A-1.1 A step-up transformer may conveniently be used to obtain the test voltage.

A-1.2 The transformer and its controlling equipment shall be capable of maintaining the test voltage up to the instant of breakdown.

A-1.3 The transformer with its associated equipment shall be capable of supplying, within wave-form limits specified in 6.1, an output current of not less than 40 mA over the full voltage range and at all leading power factors from zero to unity.

A-1.4 A transformer of output current higher than 40 mA may be required for testing materials having low electric strength (*see* 8).

A-2. VOLTAGE CONTROLGEAR

A-2.0 Smooth voltage regulation is essential and care should be taken that the combination of transformers, regulator and supply characteristics results in a wave-form specified in 6.1.

A-2.1 If a separate motor alternator set is used, the secondary voltage of high voltage transformer may be regulated by means of a resistance potential divider connected in the alternator field circuit. Smooth and fine voltage control is obtained with a suitably designed divider having a sliding contact.

A-2.2 If the supply voltage to the testing transformer is fixed, the voltage may be regulated by the use of the following devices, usually singly but possibly in combination:

a) Variable Ratio Auto-Transformer,

b) Resistance Potential Divider,

c) Induction Regulator,

d) Moving Coil Regulator, and

e) Tapped Transformer.

A-2.2.1 Preference should be given to the device having approximately straight line voltage-time curve over the desired operating range. Motor drive with variable speed control should be preferred to manual drive, because of the difficulty in maintaining a reasonably uniform rate of voltage rise with the latter.

A-2.2.2 Unless they are suitably designed, induction and moving coil regulators may cause serious wave-form distortion at the lower end of the range. Tapped transformers and variable ratio auto-transformers, however, are usually free from this defect.

A-2.2.3 If a resistance potential divider is used, wave-form distortion may occur unless harmonic in the magnetizing current of the transformer is small as compared to the current drawn from the supply. It becomes more and more difficult to comply with this condition as the kVA rating of the equipment increases.

A-3. PROTECTIVE GEAR

A-3.1 The conditions of test should be such as to prevent as far as possible any high frequency oscillation and to protect transformer when the specimen breaks down. A resistance of the order of 1 Ω/volt should be inserted in series with the dielectric under test. A water resistance may be suitable for the purpose.

A-3.2 In the primary circuit of the high voltage transformer, there should be circuit-breaker with arrangements for tripping the circuit-breaker over a wide range of current and having a no-volt-coil to protect the equipment in the event of restoration of the supply after interruption.

A-3.2.1 The circuit-breaker should be well co-ordinated with he characteristics of the test equipment and the material under test otherwise a false indication of breakdown may occur as a result of flash-over, specimen charging, leakage or corona currents, equipment magnetizing current or malfunctioning.

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